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DEVELOPMENT OF THE SOLAR COOKER JORHEJPATARNSKUA: THERMAL STANDARD ANALYSIS OF SOLAR COOKER WITH SEVERAL ABSORBER POTS

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Abstract

The present work represents the continuation of the development of a solar cooker compose parabolic concentrator of revolution type, considering a container with multiple absorber pots for cooking food, taking into account the needs of potential users, as a variant of the solar cooker Jorhejpataranskua, studying the thermal behavior of the solar cooking with three absorbers pots. In the analysis has been used the Protocol of Funk [1] to estimate cooking power. In addition we have obtained the figures of merit and the thermal performance according to Ashok & Sudhir [2].

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Keywords: Solar cooking, thermal analysis, cooking power, figures of merit, thermal performance.

1. INTRODUCTION

Continuing the development of solar cooking Jorhejpatarnskua I [3], [4], [5], and recalling that the solar cooking Jorhejpatarnskua, has one single container. Generally on our region people cooker of two to three foods for a food, so to make solar cooking more functional, need we can cook more than one food

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at a time. Thinking solve this problematic we present now a comparative study through a standard thermal analysis, using containers several (pots) in a single solar cooking.

In this paper we used the ok Funk protocol [1] for calculate "cooking power", also has been estimated the figures of merit [2] and thermal performance, for do comparing these parameters with different number of pots, at a same time a single solar cooking.

Nomenclature

R	Radius of tube.
θ	The angle is formed by the X axis and any point M.
0	The origin of a coordinate system.
$\varphi-\alpha$	Is the angle formed by the axis of the CPC and a line drawn from the origin to any point M.
F_1	First factor of merit.
d_2	Opening distance.
I	Irradiance.
T_{estag}	Stagnation temperature.
T_{amb}	Environment temperature.
C_p	Specific heat.
τ	Time.
dT	Temperature difference.
$d\tau$	Elapsed time.
m	Mass of water.
T_w	Average water temperature.
F_2	Second factor of merit.
η	Thermal performance.

2. EXPERIMENTAL DEVELOPMENT

This section presents the description of the solar cooker, experimental design, instrumentation and acquisition of data.

2.1. Description of solar cooker.

The solar cooker Jorhejpatarnskua, is a solar cooking device with characteristics of Compound Parabolic Concentrator (CPC) of revolution, this makes possible to concentrate the sun's rays in the absorber of the same, and provides safety to the user by its non-imaging optics, offers the user several advantages: no emission of light flashes that can damage eyesight, good performance in rainy season, because they use diffuse radiation, and do not require too much time for cooking. For build this solar cooker, we take the curves of Trombe-Meinel (Figure 1), considering its rotation about the axis of symmetry, thus obtaining the revolution surface in three dimensions (Figure 2), which of course is not a surface a parabolic of revolution.

$$x = R\cos\theta + R\left(\theta + \frac{\pi}{2}\right)\sin\theta \tag{1}$$

$$y = R\sin\theta - R\left(\theta + \frac{\pi}{2}\right)\cos\theta \tag{2}$$

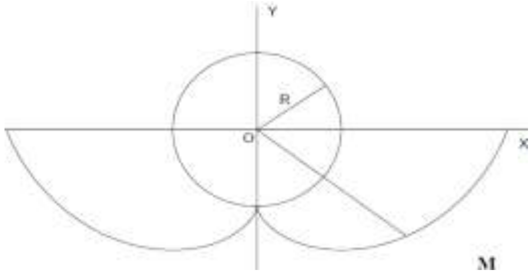

Figure 1. The surround known as cup Trombe-Meinel, (Cuevas J., et. Al) *Figure 2. CPC of revolution.*

The Trombe-Meinel surround defines a curvature that begins to "close", with height and to increase the openness of the curve (solar collection area) is given continuity by plotting a curve that defines a semi-parabola, whose equations are as follows:

$$x = \frac{d_2(1+\sin\alpha)\sin(\varphi-\alpha)}{1-\cos\varphi} - \frac{d_2}{2} \tag{3}$$

$$y = \frac{d_2(1+\sin\alpha)\cos(\varphi-\alpha)}{1-\cos\varphi} \tag{4}$$

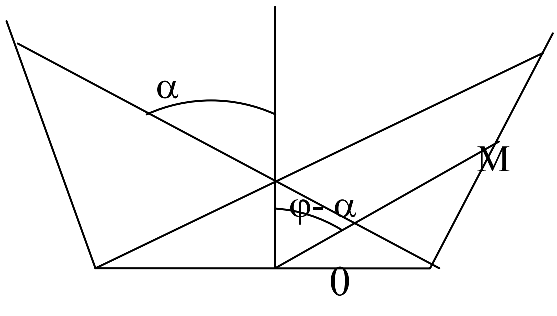

Figure 3. The Trombe-Meinel surround curves.

2.2. Development of construction process the solar cooker.

The prototype consists of CPC of revolution with an area of 0.6 m², and a support of metallic tubular (1x1in), the CPC was constructed with metal strips of 1/2x1/8in this structure of CPC is completely metal which consists of 12 strips of metal (floor of 1/2x1/8 in) joined on one of its ends to the center of the CPC, and welded, on its other end, to a top ring (tubular 1/2x1/2in) that provides stability. In structure is solar reflectors placed. In this case using anodised aluminum foil mirror finish, the support has a mechanism which causes the CPC turn rotate in two different directions to provide guidance and tilt, also has a metal basket located in the center of CPC for place the container (is a pot, where food are introduced for cooking) made with strips of metal (Figure 4).

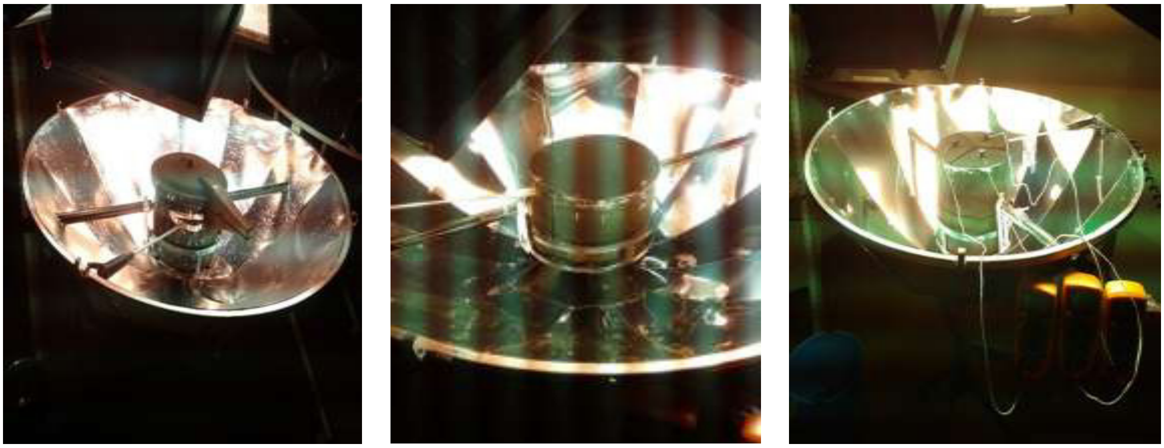

Figure 4. Solar cooker Jorhejpataranskua.

2.3. Description of absorbers containers

Solar cookers require a call in the middle for cooking, now the purpose of this article is to conduct basic tests for more than one pot, then were tested for one, two and three pots with different shapes (round, by half and thirds) figures 5, 6 and 7. Pots are stainless steel, with capacities of 6, 3 and 2 liters respectively.

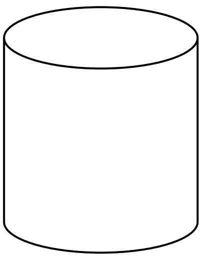

Figure 5. A pot

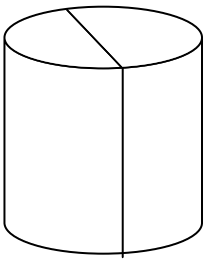

Figure 6. Two pots

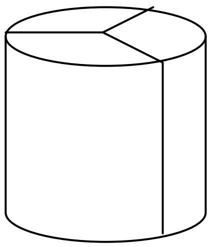

Figure 7. Three Pots

2.4. Experimental design, implementation and data acquisition

The experimental design consists of an array of three incandescent lamps of 400 Watts and two of 1000 Watts, placed at a height of 30 cm above the cooker, providing irradiance controlled conditions without the presence of wind currents, see figures 4, 5 y 6.

The instrumentation, consisted in the introduction of a K-type sensor for temperature in the concentration pot, submerged in the water to a centimeter above of the bottom, which remained in the pot without having to open it. On the other hand a sensor temperature and relative humidity was placed to measure the ambient temperature. The absorber surface temperature was measured with a temperature sensor K-type. For the irradiance data, was used a solarimeter "daystar meter", and a digital stopwatch to record the time.

Dates of water temperature, ambient temperature, relative humidity and irradiance were recorded manually, and then entered them a spreadsheet for information process and represent in a graph, using as established protocols, to obtain cooking power, the figures of merit and thermal efficiency of the solar cooker.

3. DESCRIPTION OF STANDARD TEST PROTOCOLS

To estimate the parameters considered, two tests were conducted for each of the cases:

A) Empty pot. To obtain the first factor of merit and stagnation temperature.
B) Loaded pot. To obtain the second merit factor, standardized cooking power and thermal efficiency.

A) Test to empty pot

Using experimental design described, the test was performed to empty absorber pot, the radiation lamps affecting directly on the cooker, which in turn will concentrate on the absorber pot. The data obtained for the different cases are shown in the graph (1). The horizontal axis represents time in minutes and the vertical axis the surface temperature of the pot and of the environment temperature. The maximum temperature obtained is the so-called stagnation temperature. The first factor of merit is calculated using the expression [6].

$$F_1 = \frac{T_{estag} - T_{amb}}{I} \tag{5}$$

B) Test to loaded pot

The procedure was to follow, the standard ASAE S58 [7]. Listed below are the most important criteria of the protocol. The calculation results are shown in graphs (1).

Uncontrollable variables

- The environment temperature throughout the test of 19 and 25 ° C.
- The water temperature data measured in the test were in the range between 40 and 90 ° C.

It is important to mention that the protocol takes into account other variables not controlled, such as the wind speed and the irradiance, however, in this case, these conditions have been controlled.

Controlled variables.

- Loading the pot with 4.2 kg. of water.
- The thermometer is plunged into the center of the pot, up to a centimeter from the bottom.
- Measurements every 5 minutes.
- Incident irradiance average (760 W/m^2).
- Calculation of the cooking power by multiplying the temperature gradient in the 5 minutes, by the mass of water contained in the pot, the specific heat of water divided by the elapsed time in seconds.

$$P_c = mC_p \frac{dT}{d\tau} \tag{6}$$

To calculate the derivative has been used three-point numerical formulas (see for example, [8]).
The second figure of merit is calculated according to expression [7].

$$F_2 = \frac{F_1 m_w C_p}{A\Delta\tau} \ln\left[\frac{1-\dfrac{1}{F_1}\left(\dfrac{T_{w_1}-T_a}{I}\right)}{1-\dfrac{1}{F_1}\left(\dfrac{T_{w_2}-T_a}{I}\right)}\right] \tag{7}$$

The calculation of the yield was calculated using the expression [2]:

$$\eta = \frac{m_w C_p \left(T_{w2} - T_{w1}\right)}{A\int I d\tau} \tag{8}$$

Temperature difference. This difference between the ambient temperature of each interval minus the average water temperature.

4. RESULTS

Once basic tests were performed using the solar cooker several containers simultaneously have the following results:

- The increased water temperature is maintained similarly to the cases of one two and three pots.
- Cooking power decreases depending on the number of pots, in about half to two pots and one third for three.
- Cooking power shown in graphs and is obtained with the value when you pass a trend line through the data obtained in the tests and when the temperature difference between the ambient temperature applications and the water temperature is 50 º C.

- Calculating the first merit factor difference is not observed in consider the case of one, two or three absorbers in containers hub.
- The second merit factor decreases with respect to consider a most containers absorbers.
- No heating times significantly increase considering two three containers absorbers, compared to that of only one.
- The cooking period begins when the temperature of the contents of the pot exceeds 95% of the largest temperature difference [9].
- Thermal efficiency decreases each container approximately half to one-third relative to consider thermal efficiency of a single pot.

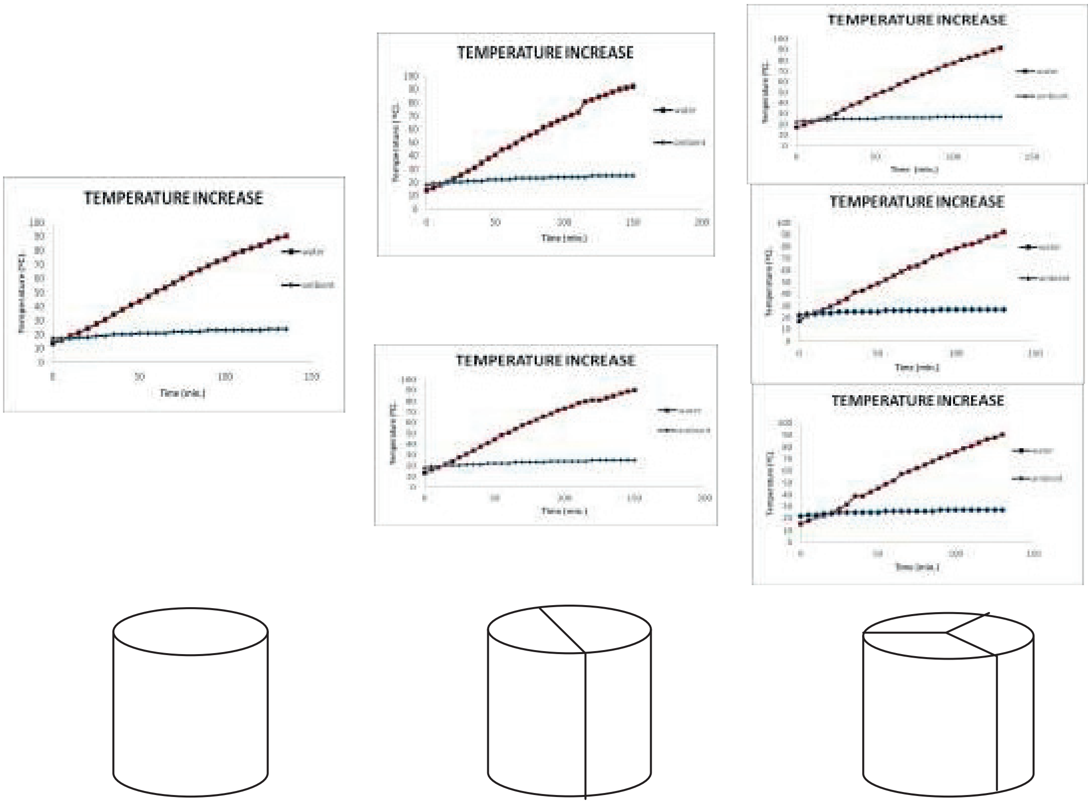

Figure 8. Increased temperature water against increasing temperature.

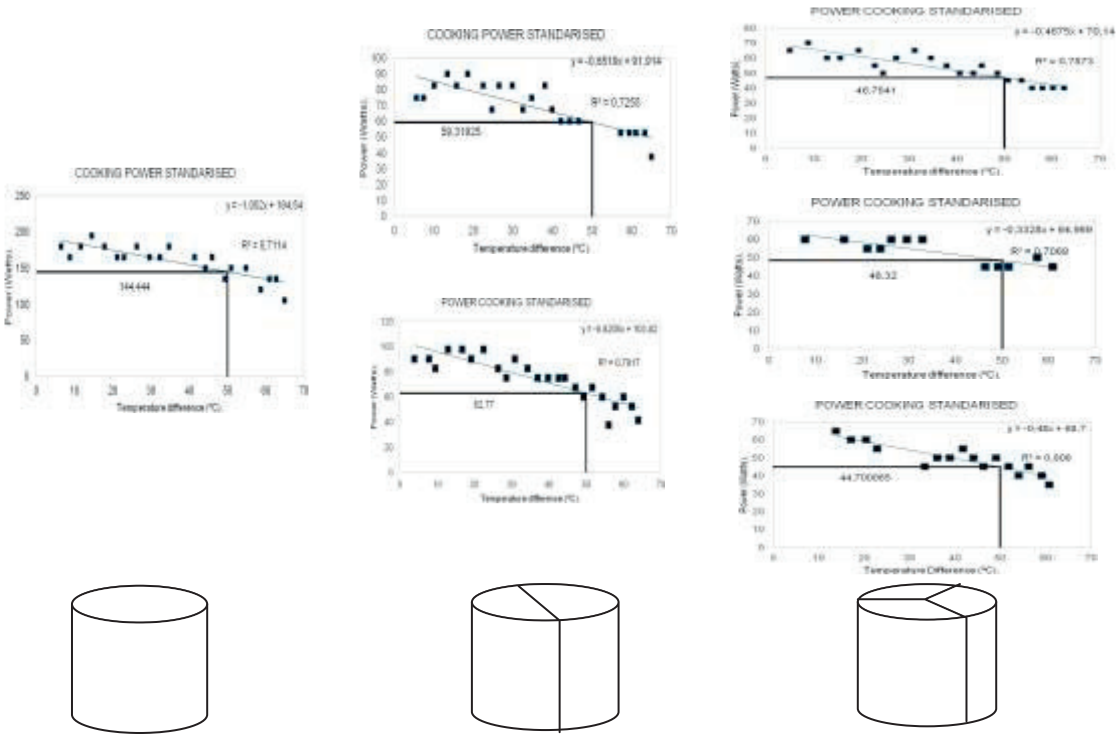

Figure 8. Cooking power for a pot, for two pots and for three pots.

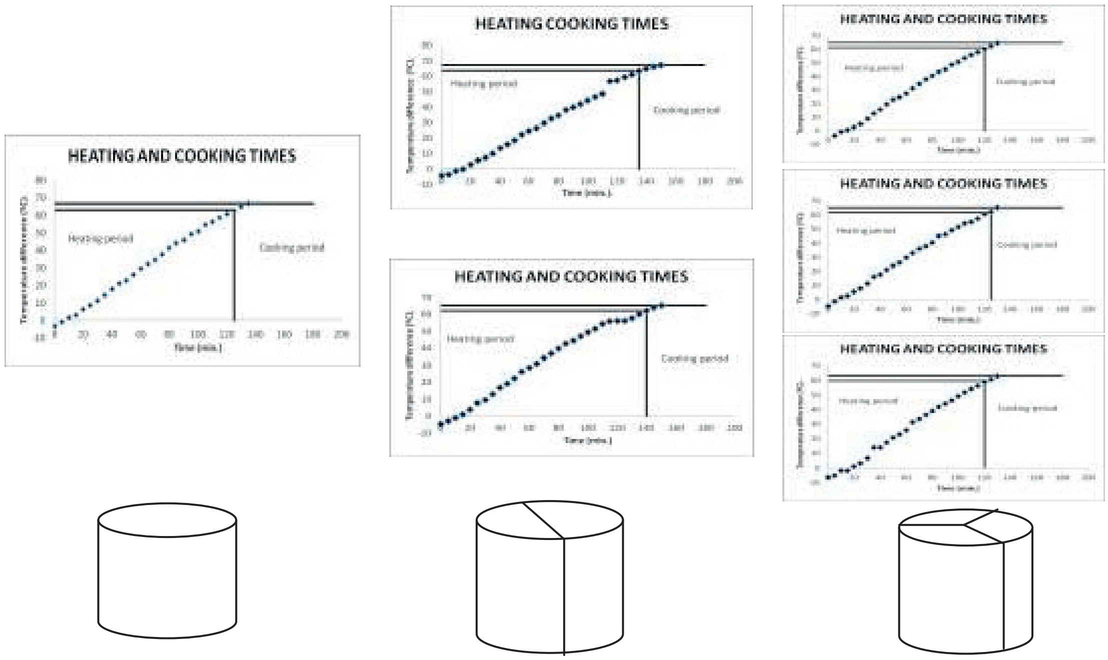

Figure 9. Periods of heating and cooking for each case one, two and three pots.

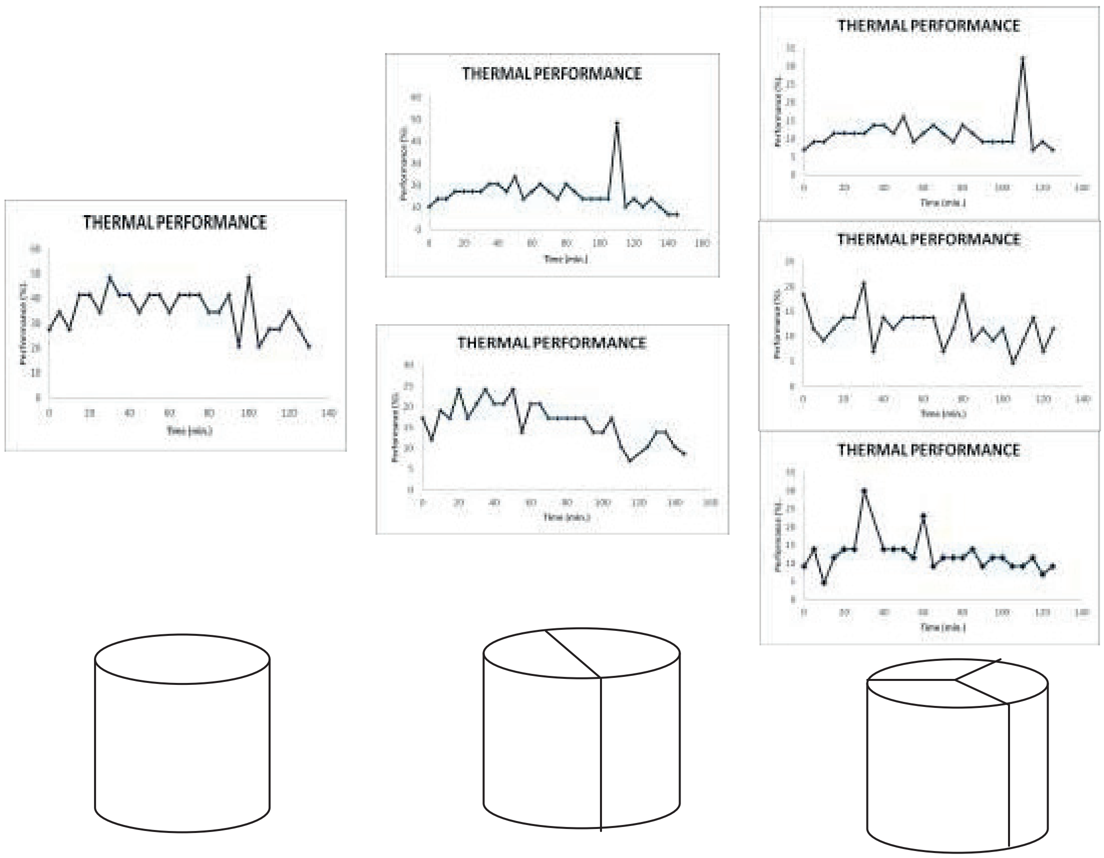

Figure 10*. *Thermal performance for each of the cases: a pot two three pots

5. DISCUSSION

According to the results found by considering several containers in the absorber of solar cooker Jorhejpatarnskua the second merit factor decreases as the number of containers, likewise cooking power and thermal efficiency decreases approximately in half and in the case three containers in a third party. Moreover, there is significant variation in the heating time, for practical purposes results in the possibility of simultaneously cook two or three meals at the same time, but in smaller amounts, enough for a family of 4-5 people, which makes functional to meet the needs of more than cooking one type of food using solar cooker.

PARAMETER		ONE POT	TWO POTS	THREE POTS
First figure of merit (K m^2/W)			0,185	0,185
			0,185	0,185
				0,185
	Average	**0,185**	**0,185**	**0,185**
Second figure of merit			0,197	0,134
			0,190	0,146
				0,123
	Average	**0,428**	**0,194**	**0,135**
Standardized cooking power (W)			59,319	46,764
			62,77	48,320
				44,700
	Average	**144,444**	**61,044**	**46,594**
Thermal efficiency (%)			16,218	11,502
			15,931	11,945
				11,856
	Average	**35,274**	**16,075**	**11,768**
Heating time (hours)			2 hrs. 15 min.	2 hrs.
			2 hrs. 20 min	2 hrs, 5 min.
				2 hrs.
	Average	**2 hr. 5 min.**	**2 hrs. 17,5 min.**	**2 hrs. 1,6 min.**

Acknowledgments

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